TECHNICAL BASIS FOR DRAFT EC AND SAR STANDARDS WITH ALLOCATION

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

July 2002

REASON: The Board is proposing the adoption of new rule I in order to establish numeric water quality standards for electrical conductivity (EC) and sodium adsorption ration (SAR) for the Tongue River, Rosebud Creek, Powder River, and Little Powder River watersheds. The adoption of new rule I is necessary to ensure that the designated uses of these waters for agricultural purposes will be protected during the development of coal bed methane (CBM) currently being proposed both in Wyoming and in Montana

The draft Environmental Impact Statement (EIS) for CBM development in Montana indicates that more than 20,000 coal bed methane wells may be developed in Montana. Each of these wells will produce about 2.5-10 gallons of water per minute. The EIS predicts that water produced during CBM development has an EC value of 2,200 µS/cm and a SAR value of 40. These values, especially the SAR values, are well above almost all of the existing instream values that are given in Table 1. In addition, the SAR value of CBM water is well above the value that will adversely impact irrigated agriculture[1,2]. If the produced water from these wells is discharged to surface waters, then the discharge must occur under an Montana Pollutant Discharge Elimination System (MPDES) permit and in compliance with all water quality laws and state-adopted standards.

Table 1. Summary data during the irrigation season (April to October) for Electrical Conductivity and Sodium Adsorbtion Ratio on Rosebud Creek and the Tongue, Powder, and Little Powder Rivers. Values shown for each station were derived from all available USGS data, and are arranged from upstream to downstream.

		Electical Conductivity (µS/cm at 25° C)			Sodium Adsorbtion Ratio		
Waterbody & Station Name	USGS Station No.	**Mean**	Minimum	Maximum	**Median**	Minimum	Maximum
Rosebud Creek							
Rosebud Cr. At Reservation Boundary near Kirby, MT	06295113	941	680	1610	0.7	0.4	0.9
Rosebud Cr. near Colstrip, MT	06295250	1363	152	2480	1.0	0.7	3.0
Rosebud Cr. at mouth, near Rosebud, MT	06296003	1793	410	3630	2.0	1.0	8.0
Tongue River							
Tongue River at Stateline near Decker, MT	06306300	479	175	980	0.5	0.2	1.0
Tongue River at the Tongue River dam near Decker, MT	06307500	533	190	958	0.7	0.3	1.2
Tongue River near Birney, MT	06307616	548	198	1030	0.8	0.3	1.4
Tongue River blw Brandenburg Bridge near Ashland, MT	06307830	693	260	1260	1.1	0.6	2.0
Tongue River at Miles City	06308500	751	274	1500	1.4	0.5	3.9
Powder River							
Powder River at Moorehead, MT	06324500	1836	255	5000	4.3	0.1	8.9
Powder River near Locate, MT	06326500	1842	338	4330	3.9	1.5	11.7
Little Powder River							
Little Powder River near the Stateline at Weston, WY	06324970	2337	373	5500	5.2	2.3	9.0

At present, the State does not have numeric standards for EC and SAR. As a result, permit limits are based upon the narrative water quality standard that prohibits substances in water in concentrations that are "harmful to human, animal, plant or aquatic life." ARM 17.30.637(1)(d). Translating the narrative standard into an enforceable permit limit on a case-by-case basis will likely be time-consuming, controversial, and may result in inconsistent or differing permit limits due to various interpretations among the permit writers. The Board is proposing numeric water quality standards in new Rule I to provide a reliable and consistent method of developing MPDES permit limits that will protect the designated agricultural uses of the affected waters.

The adoption of numeric standards would allow the use of modeling techniques to assess the cumulative effects of discharges within a watershed. Such modeling results could be used to guide permitting decisions on a water body with multiple discharges. Adopting numeric standards would also alleviate any uncertainty in determining when a violation of the State's water quality standards will occur and provide a regulatory basis for objecting to discharges originating in Wyoming or on tribal lands.

Not adopting numeric water quality standards for EC and SAR may result in inconsistent application of the narrative standards and will likely result in administrative and legal challenges of MPDES permits. It is also more likely that impacts to beneficial uses will occur due to discharges in Montana or those originating in Wyoming or in Tribal lands.

Rational for the proposed numeric standards

INTRODUCTION

These proposed water quality standards for electrical conductivity (EC) and sodium adsorption ratio (SAR) would apply to the Tongue River, Rosebud Creek, Powder River and Little Powder River and to the water bodies that are tributary to these streams. The standards are intended to protect riparian plants and plants and crops that are irrigated with water from the rivers and streams. The EC and SAR standards are intended to protect the plants and crops growing in the watersheds now and those that are likely to be grown in the future. The EC directly affects a plant's ability to take up water while the SAR affects the soils in which the plants grow rather than directly affecting the plants themselves.

Electrical Conductance (EC) is a measure of the amount of dissolved solids ("salts") in water and is generally expressed as microsiemens per centimeter (µS/cm). As the EC in the soil water increases a threshold is reached where further increases in EC cause decreases in plant growth. The EC in the soil water is directly affected by the EC of the irrigation water.

It is important to distinguish between the EC of the irrigation water and the EC of the soil water. The EC of the soil water may be higher than the EC of the irrigation water because plants and evaporation remove water from the soil but do not remove salts. Unless salts are removed or leached from the soil by excess water, the concentration of salts in the soil will build up as irrigation water is added over time.

The water in excess of the plant and evaporative needs applied to a given area of soil is termed the leaching fraction. This excess water may be supplied by irrigation and by precipitation. However, that portion of the water that is used by plants or which evaporates does not directly add to the leaching fraction. Precipitation or irrigation that occurs when the soils are saturated with water or that is stored in the soil when excess water is applied does directly add to the leaching fraction.

The sodium adsorption ratio (SAR) is a measure of the abundance of sodium relative to the abundance of calcium and magnesium in water. It is directly related to the amount of sodium that is adsorbed by soils. A high SAR in irrigation water has the potential to impair soil structure and thus the permeability of the soil leading to a lack of soil moisture. This is particularly so when the EC of the soil water or applied water is insufficient to counteract the negative effects of adsorbed sodium on soil structure. The SAR of irrigated soils equilibrates with the SAR and the EC of the applied irrigation water over time. That is, if the average SAR of the irrigation water is 5 and the EC is 1500 μS/cm the SAR and EC of the soils at and near the soil surface will also be about 5 and 1500 μS/cm within a few years.

Leaching of salts with excess irrigation water or from precipitation will lower the EC of the soil solution while its SAR will remain about the same. SAR of the soil water is controlled by the composition of the exchangeable ions – calcium, magnesium, sodium and potassium -- adsorbed on the soil. The number of adsorbed ions are far greater -- from 10 to 30 times greater -- than the number of ions dissolved in the soil water. Further, the total number of adsorbed ions does not change as a result of leaching. Consequently the reduction in EC as a result of leaching can only have a small impact on the composition of the adsorbed ions and the SAR of the soil solution. It requires only a very small fraction of adsorbed sodium to be replaced by calcium, magnesium and potassium to maintain the SAR level in the soil water that was present before leaching occurred. In other words, the exchangeable ion composition buffers the composition of the soil water with the result that while leaching will reduce the EC of the soil water, the reduction in SAR will be far smaller. As a result, leaching as a result of a rainstorm can cause SAR problems in the surface soil because the stabilizing effects of salinity on aggregate stability is lost when the EC is reduced.[3]

It should be noted that the proposed standards establish EC values that are lower than some recorded values in the streams. This means that some of the time the ambient quality will exceed the proposed standards due to natural fluctuations of EC in the water throughout the year. When the natural EC values exceed the proposed EC standards, the provisions of 75-5-306, MCA would apply. This section of the Montana Water Quality Act allows for natural exceedances of standards by providing that: "It is not necessary that wastes be treated to a purer condition than the natural condition of the receiving stream as long as the minimum treatment requirements established under this chapter are met". Thus, if the standard is 1000 μS/cm and the natural condition of the receiving water is 1500 μS/cm, a discharge could occur as long as the discharge did not raise the instream concentration above 1500 μS/cm.

<u>Derivation of EC standards for the Irrigation Season (April 1- Oct 31)</u>

The Board is proposing to adopt numeric standards for EC that are applicable during the irrigation season when the protection of water quality for agricultural use is a concern and a maximum value for EC applicable when irrigation is not a concern. Under New Rule I (3) through (7), the time period between April 1 and October 31 is being proposed for the irrigation season standards, because that is the time that irrigation in the affected area normally occurs. During the remaining months of the year (November 1 through March 31), an EC standard of 2000 µS/cm is being proposed to protect riparian vegetation throughout the affected watersheds. *See* New Rule I (2). The EC value of 2000 is being proposed because it reflects the natural water quality in the Powder River and Little Powder River, which have healthy riparian vegetation even though they have recorded mean values of EC that range between 1800 and 2000.

In order to derive standards for EC during the irrigation season the Board considered the type of plants being irrigated in the affected area, the sensitivity of those plants to EC, the leaching fractions that are occurring, and the correction factors that should be applied due to precipitation.

The plants being irrigated in the affected area are summarized in Table 2[4]. Table 2 was compiled by the Department after receiving more than 200 responses to several surveys asking the agricultural community what type of plants they cultivate each year. Column 2 of Table 2 lists the soil water salinity thresholds (as EC) for each of these plants[5]. When these thresholds are exceeded plant or crop yields begin to decrease. The standards for EC proposed under New Rule I are intended to protect the most salinity sensitive plants listed in Table 2 that are produced in the affected area, such as field beans.

The standards for irrigation season also vary depending upon the type of irrigation used in the various watersheds and the differing leaching fractions that occur as a result of these irrigation practices. For the Tongue River, a leaching fraction of 15% is assumed as a basis for the EC standards. This is assumed because a leaching fraction of 15 % is typical of conventional sprinkler and flood irrigation, which is used in the basin[3]. Sprinkler systems are relatively rare in the basin. Most of the irrigation in the basin is done with conventional or modified flooding methods. In distinction, the Board assumed a 30% leaching fraction for the Powder River standards, because the work of deMooy and Franklin[4] indicates that a leaching fraction of 30 % is reasonable for flood irrigation in the Powder River Valley. Finally, the Board did use a leaching fraction to derive EC standards for Rosebud Creek because there is some conventional flood irrigation in the lower reaches[5] even though most of the irrigation upstream in the Rosebud Creek Valley is sub-irrigation. The leaching fraction concept is not applicable to those areas of sub-irrigation.

The leaching fractions discussed above are averages and it is assumed that leaching is uniform throughout a field. In practice the leaching fraction is not uniform throughout a field and local impacts due to salinity can occur. Although these impacts can not be quantified, they should be relatively minor.

The concentrating effect of EC in the soil caused by evaporation and the plant withdrawing water, but leaving the salts in the soil, are summarized in figure 1 in Hansen et al.[8] and reproduced here as Figure 1. Although this is not the original source of the data, this document is widely available and the figure is included as a convenience to the reader.

For water spreader systems a leaching fraction of 30 % is not reasonable[3]. The only time that leaching can occur in the upper 2 – 3 feet of soil in a spreader dike system is when infiltration of water from rain, snowmelt, and operation of the spreader dike system wets the soil to a depth of depth of 5 – 7 feet. About 14 inches of infiltrated water would be required in excess of evaporation from the soil surface and transpiration by the vegetation (evapotranspiration). Assuming 6 inches of water would infiltrate from the operation of the spreader dike system, the remaining 8 inches would need to come from rain and snowmelt. The months of March through mid-May are the only times during the year when the total infiltrated water may be 14 inches greater than evapotranspiration. We assume this usually occurs once out of every 8 to 10 years.

Table 2. Threshold of salinity (as electrical conductivity, EC) impacts to the growth of plants commonly grown in the Powder and Tongue region. Assumed leaching fractions associated with each cultivation practice are shown. For each plant and leaching fraction, an increase in irrigation water salinity beyond the table value will cause plant yield decreases.

		Irrigation water EC (µS/cm): Threshold for no-impact to growth			
		Rosebud Creek†	Tongue River	Powder & Little Powder Rivers	Tributaries
		(Conventional flood irrigation) ‡	*(Conv. flood & Sprinkler)* ‡	*(Flood irrigation)* #	*(Water Spreader)* ¢
Name of Plant or Crop	**Soil water EC threshold**	**15%** Leaching Fraction	**15%** L.F.	**30%** L.F.	
Strawberry	1000	(660) 990	(660) 990	(960) 1920	
Field beans* & Green beans	1000	(660) 990	(660) 990	(960) 1920	
Carrots	1000	(660) 990	(660) 990	(960) 1920	
Radish	1200	(795) 1193	(795) 1193	(1155) 2310	
Onions	1200	(795) 1193	(795) 1193	(1155) 2310	
Lettuce	1300	(860) 1290	(860) 1290	(1250) 2500	
Clover (all types)*	1500	(990) 1485	(990) 1485	(1445) 2890	500
Orchard grass*	1500	(990) 1485	(990) 1485	(1445) 2890	500
Corn* & Sweet corn	1750	(1126) 1689	(1126) 1689	(1640) 3280	
Alfalfa*	2000	(1320) 1980	(1320) 1980	(1930) 3860	500

* Field or commerical crops

† Much of the cultivation in the Rosebud Creek basin is done by subirrigation. In these cases, the soil water EC thresholds apply.

‡ Precipitation correction factor of 1.5 has been applied to values in the right hand, unbracketed column. Left hand, bracketed column values are uncorrected.

Precipitation correction factor of 2.0 has been applied to values in the right hand, unbracketed column. Left hand, bracketed column values are uncorrected.

¢ See text for details of how these EC standards were developed.

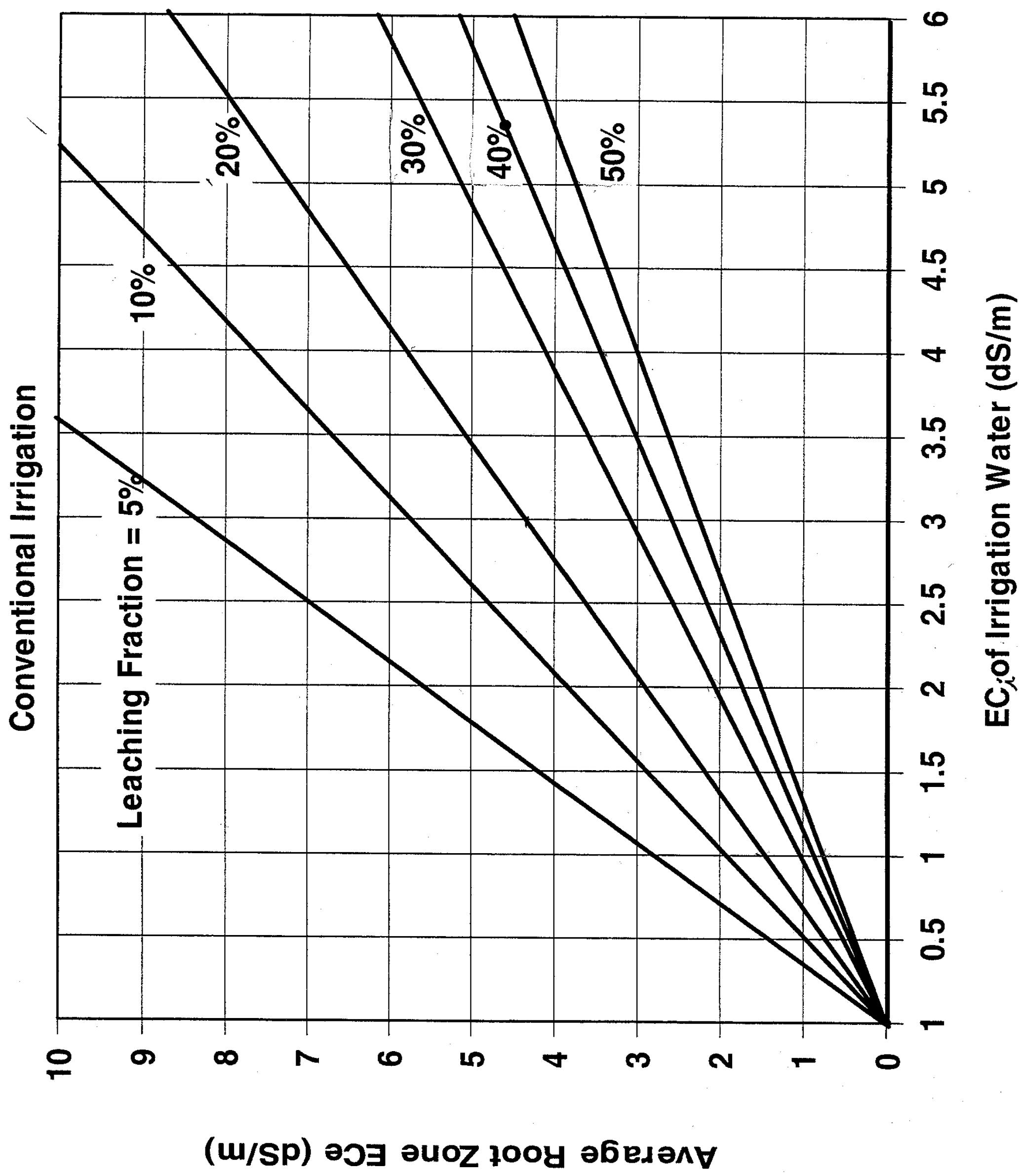

Figure 1. Assessing the maintenance leaching fraction under conventional irrigation methods.

Figure 1. Relationships between leaching fractions, irrigation water and soil water ECs

Figure 1 is used to determine the permissible value of EC in the irrigation water based upon a maximum permissible level of EC in the soil water and a leaching fraction. As discussed earlier, the maximum permissible EC in soil water is dependent upon the plants or crops grown. For example, the maximum permissible EC in the soil for alfalfa is 2000 μS/cm, then the horizontal line labeled 2 (2000 μS/cm is 2 dS/m) is found on the left side of the figure labeled "Average Root Zone EC (dS/m), then go to the point where this line and the line labeled leaching "fraction = 5 %" meet, then drop straight down to about 0.7 on the line labeled "ECi of Irrigation Water (dS/m)". Thus, if the leaching fraction is 5 %, the EC of the soil water will be about 2.9 times the EC of the irrigation water.

Irrigation systems

Figure 1 was used to calculate the "uncorrected" EC values given in parentheses for each leaching fraction listed in Table 2. These values represent the values of EC in the irrigation water that will cause no decrease in yield for sensitive crops that are grown in the Powder River Basin if precipitation is ignored. These values differ for the various leaching fractions.

The diluting effect of precipitation must also be considered in order to correctly calculate EC values for irrigation water that will protect irrigated plants. The average annual total precipitation at Brandenburg, Montana for the period from 5/1/1956 to 12/31/2001 is 14.35 inches[9]. This is assumed to be representative for the irrigated areas in the basin. The diluting effect of this precipitation is dependent on the amount of irrigation water that is applied. According to deMooy and Franklin[6], the effective infiltration of precipitation in the region is about 80%. That is, some of the precipitation simply runs overland to the nearest drainage without soaking into the soil. This is especially true during thunderstorms, which are common in the region. An effective precipitation of 11.48 inches (0.8 X 14.35 = 11.48) is a reasonable value for calculating the correction factor.

In the Tongue River Valley plant growth and evaporation require about 30 inches of water per growing season. Conventional flood irrigation throughout the valley is generally applied in amounts that result in leaching fractions of about 15%. At a leaching fraction of 15% an additional 4.5 inches (15% of 30 inches) is needed during the growing season for a total of 34.5 inches. Of this, about 11.5 inches is normally supplied by precipitation, which has no salts. Using the following formula, the salt content of about 24.5 inches of irrigation water is diluted by 11.5 inches of precipitation to calculate a correction factor of 1.5. For these reasons, the Board used a precipitation factor of 1.5 to derive the EC standards for the Tongue River basin.

$$\text{Correction Factor} = (\text{Depth}_{(\text{precipitation})} + \text{Depth}_{(\text{Irrigation water})}) / \text{Depth}_{(\text{Irrigation water})}$$

The correction factors are applied to the “uncorrected” threshold values (in parenthesis) for EC in the irrigation water to calculate the corrected threshold values. For example Table 2 lists the irrigation water EC thresholds are 990 μS/cm (660 X 1.5 = 990) for no impact on the yield of strawberry, field beans (a commercial crop in the area) and carrots at a leaching fraction of 15 %.

These no impact levels for irrigation water EC also apply to the limited conventional irrigation on Rosebud creek. Most of the irrigation on Rosebud Creek is through the subsurface and no water or salts are applied to the surface and thus the leaching fraction concept and precipitation correction factors do not apply for this irrigation. However, because there is some conventional flood irrigation on the lower reaches of the stream the standards developed for the Tongue River system also apply to Rosebud Creek.

For the Powder River most of the irrigation consists of the application of water when sufficient water of acceptable quality is available. The Department estimates that over the long term, 6 to 12 inches of irrigation water are available. Based upon 12 inches of available irrigation water and 11.5 inches of precipitation the correction factor would be about 2.0. If there is only 6 inches of irrigation water available the correction factor is about 3.

Spreader dike systems

Spreader dike irrigation is common on the tributaries to Rosebud Creek and the Tongue, Powder, Little Powder Rivers. Unfortunately, it appears that there is no data on the quality of water used in these systems. Furthermore it is not practical to get such data because the water quality will vary from site to site and runoff to runoff. It is possible to calculate the maximum average EC of this water that would allow the continued operation of these systems. This has been done as follows.

Leaching will occur only under wet spring conditions when the total infiltrated water from rain, snowmelt, and operation of the spreader dike system would exceed evapotranspiration by about 14 inches. This probably occurs once out of every 8 to 10 years. In the intervening years salts in the water applied with the spreader dike system accumulate in the upper 3 feet of soil increasing the salinity of the soil water. Estimates of the increase in salinity can be made if the following assumptions are made. 1. The rate of water application is 6 inches per year. 2. The average initial soil salinity is 0.25 dS/m. 3. The water holding capacity of the soil is 2 inches per foot[6]. 4. The salinity is measured on water extracts obtained on saturated soil pastes that have a water content that is two times higher than that of the soil. 5. No leaching. 6. No significant removal of salt in the harvested alfalfa. Based on these assumptions, the EC of the applied water should not exceed 500 µS/cm in order to prevent salt accumulation in 10 years to levels that can reduce the yield of alfalfa by more than 10 %. Alfalfa is the major crop grown with these systems. If the average EC of the applied water was 600, the average root-zone salinity could reach levels in 8 to 10 years that range from 2.6 – 3.2 dS/m. For alfalfa these salinities correspond to yield declines that range from 10 to 17 %.

Derivation of SAR standards

A high SAR in irrigation water has the potential to impair soil structure and thus the permeability of the soil. The effects of high sodium adsorption ratios decrease as the salinity of the water increases. This relationship is shown in Figure 2.

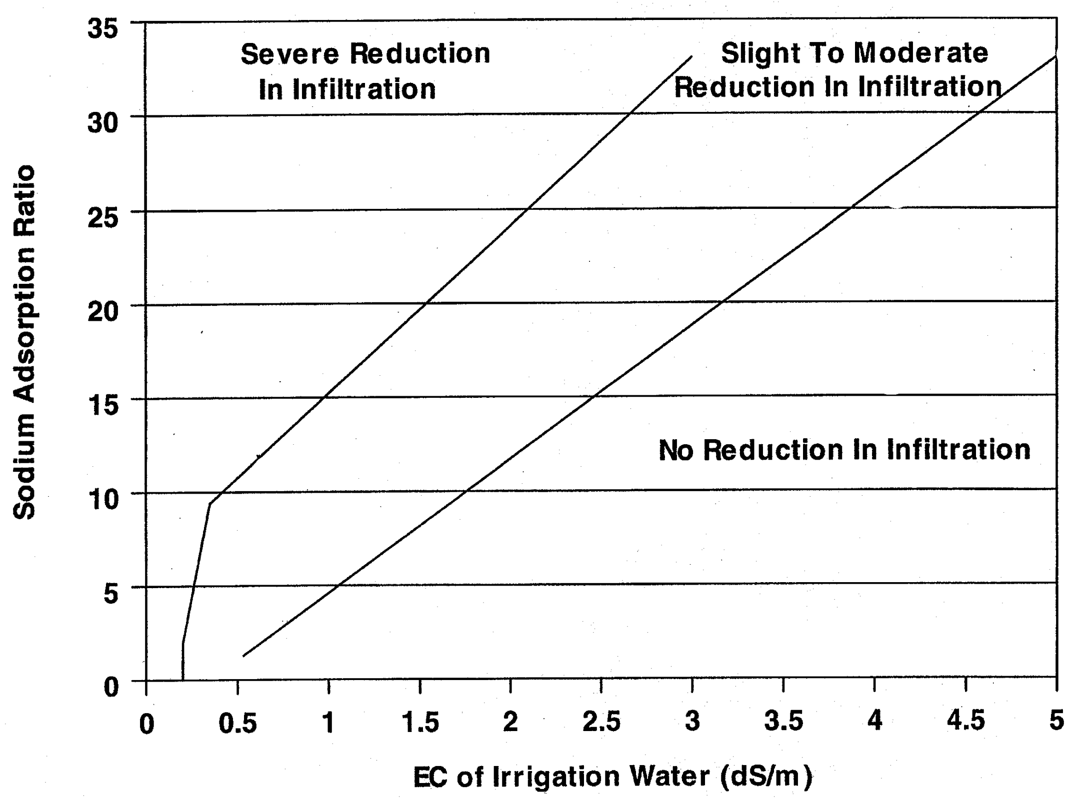

Figure 2. Relationship between EC and SAR and the effect on infiltration of water into the soil.

The lower line and the area below it reflect conditions of EC and SAR for which there will be no reduction in infiltration under normal field conditions. This line can be mathematically expressed as SAR=(EC x 0.0071) - 2.475. The draft SAR standard uses this formula as a standard. The standard is whatever number results from using this formula and the EC at a given time. However, this relationship would not apply at very low or high ECs or to spreader systems.

At an EC of 350 µS/cm or less the formula would indicate that the allowable SAR would be less than zero. Because of this nonsensical result, the formula would not apply when the EC is less than 350 µS/cm. Although EC's less than 350 do occur in the basin they are not common as can be seen from Table 1.

At EC's above 1000 µS/cm a SAR limit of 5 is justified because the salinity is adequate to counteract the effects of adsorbed sodium. That is, no reduction in infiltration would be expected. See Figure 2. Higher EC's at an SAR of 5 would increase the likelihood that no reduction in infiltration will occur under normal field conditions.

On the other hand, this figure does not consider the effects of rain fall on the EC and the SAR. Should rainfall reduce the salinity in a soil irrigated with a water with a SAR of 5, there is a risk that infiltration rates will be reduced.

For spreader dike systems, infiltration of rainfall and snowmelt is crucial to maintaining soil salinity at levels that have little or no impact on crops, particularly alfalfa. The EC of rainfall is near zero. Thus during a wet spring, the salinity of the soil surface can approach zero due to leaching by rain during times when the spreader dike system can not be operated. The SAR of the captured runoff water should not result in adsorbed levels of sodium in the soil that will impede the infiltration of rain.

Summary of proposed standards

The proposed standards for the irrigation season are based on protecting sensitive plants given reasonable leaching fractions and precipitation correction factors. The EC standards values are rounded to the nearest 100 µS/m. The proposed standards and existing water quality are summarized in Table 3. Note that for the Tongue River there are different standards for different segments of the river. This is discussed below in "Need for an Allocation Process".

Assimilative Capacity, Need for an Allocation Process, and Approach Used for Allocations

Assimilative Capacity

The difference between the existing concentration of a water quality parameter and the parameter's standard, given that the current instream concentration is lower than the standard, is referred to as assimilative capacity. For example, if the EC standard is 1000 µS/cm and the instream concentration is 750 µS/cm, there are 250 µS/cm of assimilative capacity. For EC in Rosebud Creek, the Powder and the Little Powder Rivers there is no assimilative capacity because mean EC for those waterbodies is essentially at or above the standard (Table 3). However, there is assimilative capacity in the Tongue River (Table 3). The highest mean EC in the Tongue River, 751 µS/c at Miles City, provides 249 µS/cm of assimilative capacity with a standard of 1000 µS/cm. It is not unusual that EC is the highest at the most downstream point (in this case Miles City), because salinity is fairly conservative (it is not used up biologically) at these concentrations and generally increases in a downstream direction.

There has been some concern expressed that the mean EC at the Miles City station (USGS gage 06308500) may be abnormally high, due to major water withdrawals by the TY ditch that is 12.3 river miles upstream from the station. The Department examined the increase in EC per unit

Table 3. Proposed standards for electrical conductivity and sodium adsorbtion ratio (SAR) and statistical summaries for Rosebud Cr. and the Tongue, Powder, & Little Powder Rivers during irrigation season (April to Oct). Station summary values were derived from all available USGS data.

Waterbody & Station Name	USGS Station No.	Electrical Conductivity (µS/cm at 25° C) Mean	Maximum	Proposed Standard	Sodium Adsorbtion Ratio Median	Maximum	Proposed Standard† ‡
Rosebud Creek							
Rosebud Cr. At Reservation Boundary near Kirby, MT	06295113	941	1610	**1000**	0.7	0.9	**0.75 - 5.0**
Rosebud Cr. near Colstrip, MT	06295250	1363	2480	**1000**	1.0	3.0	**0.75 - 5.0**
Rosebud Cr. at mouth, near Rosebud, MT	06296003	1793	3630	**1000**	2.0	8.0	**0.75 - 5.0**
Tongue River							**0.75 - 5.0**
Tongue River at Stateline near Decker, MT	06306300	479	980	**530**	0.5	1.0	**0.75 - 5.0**
Tongue River near Birney, MT	06307616	548	1030	**700**	0.8	1.4	**0.75 - 5.0**
Tongue River blw Brandenburg Bridge near Ashland, MT	06307830	693	1260	**900**	1.1	2.0	**0.75 - 5.0**
Tongue River at Miles City	06308500	751	1500	**1000**	1.4	3.9	**0.75 - 5.0**
Powder River							**0.75 - 5.0**
Powder River at Moorehead, MT	06324500	1836	5000	**1900**	4.3	8.9	**0.75 - 5.0**
Powder River near Locate, MT	06326500	1842	4330	**1900**	3.9	11.7	**0.75 - 5.0**
Little Powder River							**0.75 - 5.0**
Little Powder River near the Stateline at Weston, WY	06324970	2337	5500	**1900**	5.2	9.0	**0.75 - 5.0**
Tributaries to all waterbodies above	na	*	*	**500**	*	*	**0.75-5.0**

*Insufficient data available to characterize the water quality parameter.

†SAR values within the ranges are calculated as a function of EC, using the equation: SAR = (EC X 0.0071) - 2.475. If a calculated SAR value is outside of the range due to a particularly low or high EC value, the SAR will be either the minimum or maximum, respectively, of the range in the table.

‡See text for details on the derivation of the tributaries' SAR standard.

river mile for the segment of the Tongue River around the Miles City station and compared the values to those of the Tongue River upstream, from the Decker Dam to the "near Ashland" USGS station (gage 06307830). This was done for the irrigation season, April to October. The EC per unit river-mile for the Miles City segment of the Tongue River is well within the range found in upstream locations. Therefore, it does not appear that the Miles City station values are high relative to what one might expect given the upstream tendencies.

Need for an Allocation Process

An allocation process would ensure that the CBM resource can be fairly developed by all interested parties. In this case, there are four political entities that have a stake in CBM development in the Tongue River Basin; Montana, Wyoming, the Northern Cheyenne, and the Crow. Because salinity tends to be conservative, there exists the potential that the most upstream CBM developer could use up all of the river's assimilative capacity thus precluding development for downstream CBM development. Allocation assures up front that each interested party will receive its fair share of the potential development.

Allocation Process

The allocations for each Tongue River segment shown in Table 3 above were derived using an unbiased, equitable approach. Based on the predicted density of reasonably foreseeable CBM wells in the Tongue River watershed[10,11], the number of potential wells for each political entity was calculated using the political entities' surface-area within the watershed. Each political entity was then allocated a proportion of the EC assimilative capacity equal to their proportion of the total potential wells in the drainage. Wyoming, for example, has 18% of the reasonably foreseeable wells and therefore was allotted 18% of whatever assimilative capacity the river might have. Allocations were thus divided as follows; 18% for Wyoming, 4% for the Crow, 6% for the Northern Cheyenne, and 72% for Montana. The mean irrigation season (April to October) EC was used to represent background EC for the river. Each entities' allotted proportion of the EC assimilative capacity was then "mapped" in a simple spreadsheet model so that one of the four Tongue River sampling stations (Table 3) could be used to determine what the maximum allowable EC could be at the station, given that EC could not exceed 1000 µS/cm at the Miles City gage. EC was assumed to be conservative and thus accumulative in a downstream direction. Sub-allocations for Montana and the Northern Cheyenne were also "mapped" along the river gradient, to accurately represent the fragmented political geography of the drainage. The model outputs generated are those shown for each Tongue River station in Table 3, rounded to the nearest 10^{th}.

Derivation of maximum EC standard for November through March in order to protect riparian plant communities

Water moving through the alluvium provides water for plant growth in the riparian zone. The riparian zone is continually exposed to water. In addition, in some places the water in the alluvium will tend to "wick" to the surface and evaporate leaving the salts at or near the soil surface. An increase in the salinity of the water may result in an increase in the accumulation of salt. Such an increased accumulation could impact the riparian plant communities.

The sensitivity of native riparian and wetland plants to SAR and salinity is not well known. However extensive riparian vegetation occurs in the basin, even on the Powder River where the average EC is over 1800 μS/cm. Setting a maximum EC standard of 2000 μS/cm should protect riparian communities.

References

[1] Ayers, R. S., and D. W. Westcot. 1985. *Water Quality for Agriculture,* FAO Irrigation and Drainage paper 29 (Rev 1), Food and Agriculture Organization of the United Nations.

[2] Oster, J.D. 1994. Irrigation with poor quality water. Agricultural Water Management 25:271-297.

[3] Oster, J. D. Extension soil and Water specialist and Adjunct Professor, University of California, Riverside, CA. Personal Communication 2 June 2002

[4] Unpublished data, DEQ files

[5] Maas, and S. R. Grattan. 1999. Drainage Monograph #38, ASA

[6] deMooy, C.J., and W.T Franklin. 1977. Determination of maximum tolerable salinity levels for continuous irrigation on various soils along the Powder River. Yellowstone-Tongue APO. Fort Collins, CO.

[7] McRae, Clint, rancher, Rosebud Montana, personal communication, 21 June 2002

[8] Hansen, B.R., S. R. Grattan, and A. Fulton. *AGRICULTURAL SALINITY AND DRAINAGE, University of California Irrigation Program,* University of California, Davis, revised 1999

[9] Western Regional Climate Center, wrcc@dri.edu

[10] BLM. 2001. Water resources technical report. Montana statewide oil and gas environmental impact statement and amendment of the Powder River and Billings resource management plans. Prepared for the BLM Miles City Field Office by All Consulting, June 2001.

[11] Wyoming BLM

H:\DEQRuletrak\7-Ruledevtracking\In-Progress\WQA\ec-sar-stds\RATIONALallocate.doc